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MEAT COLOUR DIFFERENCES BETWEEN ALPINE, BALKAN AND SERBIAN WHITE GOAT BREEDS SLAUGHTERED AT 18 KG OF BODY WEIGHT

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Abstract: Meat colour was evaluated in 36 goat kids of both genders equally from three breeds: Alpine, Balkan and Serbian white breed. Animals were slaughtered at 18 kg of body weight and three muscles were analysed for colour characteristics and pH value: *m. longissimus lumborum*, *m. psoas major* (tenderloin) and *m. semimembranosus*. pH values differ significantly only for *m. longissimus lumborum* muscle, whereas Balkan kids had a significantly higher pH value than Alpine and Serbian white ($p<0.001$). The goat breed significantly affected meat CIEL*a*b* values for all muscles analysed. Lightness (L*) was generally the highest for Balkan and lowest for the Alpine breed. The differences in redness (a*) and Chroma values (C*) were not significant, while the yellowness only differed for *m. longissimus lumborum* muscle, whereas Serbian white kids had higher b* values compared to Alpine kids. As a colour saturation characteristic, the hue angle was higher in meat from indigenous breeds (Balkan and Serbian white) than in the Alpine breed.

Keywords: meat colour, pH value, indigenious goat breed

Introduction

The total number of goats in the world is about 1 billion, of which a majority are in developing countries (Pophiwa et al., 2020). The lower amount of subcutaneous and intramuscular fat, favourable carcass composition and high meat quality are the main drivers behind the trend in increasing their overall number in the world (Stanišić et al., 2012). However, this increase is not worldwide significant due to its low economic significance compared to other animal breeds (Tshabalala et al., 2003). Goat meat also has more polyunsaturated fatty acids when compared with other ruminants, like cattle and sheep (Banskalieva et al., 2000). The popularity and acceptability of goat meat vary considerably between countries and ethnic groups. In South Europa and Latin America, meat from younger goats is popular, while meat from adult

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goats is favoured in the Indian subcontinent (Naude and Hofmeyr, 1981). Countries like Greece, Spain, Italy and France are significant producers since they produce two-thirds of the total amount of goat meat produced in Europe (Ripoll et al., 2011).

In Serbia, goats are traditionally raised in a smallholder farming area with 1-2 animals per household, mainly in the mountainous. The production of goats in Serbia is mainly focused on dairy breeds. A significant number of goats in Serbia are from autochthonous breeds, such as Balkan and Serbian white goats. According to Žujović et al. (2011), the composition of the goat population is Balkan breed (47%), various hybrids (35%), Serbian white breed (15%) and Alpine (2–3%). Even though the main product obtained from goats in Serbia is milk, meat production should not be neglected.

Consumer evaluations and preferences of meat quality are primarily focused on freshness, colour, degree of marbling and texture. Meat colour is one of the most critical characteristics of meat as it influences consumer purchasing choices (Zervas and Tsiplakou, 2011). Meat which is more yellow and darker in colour is usually perceived to be obtained from older animals, so consumers mostly prefer pale or pink meat (Kosum et al., 2003). It is well known that meat colour is affected by many factors in the feeding–breeding system (Alcalde and Negueruela, 2001), of which animal breed, age, diet and meat cut are the most important ones (Priolo et al., 2001; Dhanda et al., 2003). Additionally, after slaughter, the muscle undergoes ageing, which changes the meat's colour, texture and flavour (Xiao et al., 2022).

To date, the information about the meat colour characteristics of indigenous Serbian goat breeds could be more extensive. Hence, this study was designed to provide valuable information regarding meat colour differences between two indigenous breeds (Balkan and Serbian white) and one noble goat breed (Alpine).

Materials and methods

All the animal management was conducted respecting animal welfare. The trial was carried out in the experimental farm of the Institute for Animal Husbandry (Belgrade, Serbia) on three groups of goat kids: Alpine, Balkan and Serbia white breed. Each group consisted of 12 kids (6 male and 6 female), reared under an intensive system and fed with grass hay and concentrate. Hay consisted of Festucetum vallesiacae grass mixture. The composition of the concentrate used in the feeding was as follows: proteins (16.0%), moisture (13.5%), fibre (8.0%), ash

(8.0%), calcium (0.8–1.0%), phosphorus (0.5–0.7%) and sodium (0.2–0.3%), with an addition of vitamins and minerals. Feeding was ad libitum until slaughter.

After reaching 18 kg of body weight, all animals were transported to the slaughterhouse. They were denied feed 12 h before slaughter, but they had free access to water. Animals were electrically stunned and slaughtered according to standard commercial procedures. After removing skin and head, front and rear legs and evisceration, carcasses were placed in cold storage at 4 °C for the next 24 hours. All meat samples (*longissimus lumborum*, *psoas major* and *semimembranosus*) were taken from the left side of the cooled carcasses.

The pH value of meat was measured by pH-meter Hanna, HI 83141 (Hanna Instruments, USA), equipped with a puncture electrode. Before measuring, the pH meter was calibrated using standard phosphate buffers (ISO 2917, 1999).

The colour of freshly cut meat surface, expressed in CIE L*a*b* colour coordinates, was measured after 30 min blooming time (samples were stored in contact with air at room temperature) using Chromameter CR-400 (Minolta Co. Ltd, Tokyo, Japan) with 8 mm aperture size, D65 illuminant and a 0° standard observer angle. Chromameter was calibrated using a white ceramic plate (Y=87.2, x=0.3173; y=0.3348; 0° observer). Three readings were done on non-overlapping areas of the muscles and the average value was used for data analysis. The a* and b* values were used to determine chroma = $(a^2 + b^2)^{1/2}$ and hue (θ) = tan−1(b/a) according to Tapp et al. (2011).

In order to determine the effect of breed on the colour characteristics of meat, a single-factor analysis of variance was performed using SPSS 20.0 software (IBM SPSS Statistics, Version 20, IBM Corp, USA). If the effect of the breed was found significant, the LSD test was used to identify the significant differences between groups. All differences were considered significant at $p<0.05$ and data are presented as mean value ± standard deviation

Results and discussion

The final pH value of meat is an important indicator that significantly affects meat colour characteristics (Liu and Chen, 2000), as the pH of goat muscle declines significantly after slaughtering, affecting the overall meat quality (Hamoen et al., 2013). The differences in pH values between breeds per muscle are shown in Tables 1, 2 and 3. There were no significant differences among breeds within a muscle group ($p>0.05$), except for *longissimus lumborum*, where Balkan goats had a significantly higher pH value compared to Alpine and Serbian white (Table 2). Since higher meat pH can indicate pre-slaughter

stress, this difference could be explained by the different responses of Balkan goats to pre-slaughter handling (Dhanda et al., 2003). In the research of Bañón et al. (2006), Santos et al. (2007), Peña et al. (2009) and Ripoll et al. (2011), the final pH values for goat muscles were higher than 5.5, which is in agreement with this experiment. England et al. (2016) stated that the final meat pH value depends on the breed and muscle type of goats, which can explain the differences found for *longissimus lumborum* in this research (Table 2). Gawat et al. (2022) showed that the average pH values of raw goat meat ranged from 5.76 to 5.98, regardless of the breed.

Table 1. pH value and colorimetric parameters of *Longissimus lumborum* of kids

Parameters	Alpina	Balkan	Serbian white	p-value
pH	5.76 ± 0.14^{a}	6.28 ± 0.10^{b}	5.64 ± 0.17^{a}	<0.001
L*	34.02 ± 2.13^{a}	37.67 ± 1.88^{ab}	35.80 ± 1.98^{b}	0.002
a*	11.02 ± 2.60	9.20 ± 1.29	11.83 ± 0.79	0.099
b*	6.19 ± 1.55^{a}	6.44 ± 1.26^{ab}	7.26 ± 1.41^{b}	0.030
h	29.37 ± 2.22^{a}	35.08 ± 1.64^{ab}	31,53 ± 1.86^{b}	0.001
C*	12.65 ± 2.90	11.24 ± 2.79	13,89 ± 2.52	0.101

Table 2. pH value and colorimetric parameters of *Psoas major* of kids

Parameters	Alpina	Balkan	Serbian white	p-value
pH	6.15 ± 0.32	6.24 ± 0.44	6.07 ± 0.29	0.101
L*	34.29 ± 1.73^{a}	38.60 ± 0.71^{b}	35.08 ± 1.44^{a}	<0.001
a*	15.40 ± 2.16	13.58 ± 1.15	15.07 ± 1.55	0.285
b*	7.59 ± 0.99	8.58 ± 0.67	8.19 ± 0.37	0.064
h	26,33 ± 1.31^{a}	32.27 ± 1.01^{b}	28.50 ± 1.43^{b}	<0.001
C*	17.19 ± 2.32	16.07 ± 2.21	17.17 ± 1.74	0.668

Table 3. pH value and colorimetric parameters of *Semimebranosus* of kids

Parameters	Alpina	Balkan	Serbian white	p-value
pH	5.90 ± 0.43	6.07 ± 0.47	5.91 ± 0.33	0.098
L*	34.29 ± 0.99^{a}	36.55 ± 1.88^{b}	35.79 ± 2.42^{ab}	0.016
a*	12.06 ± 1.75	11.70 ± 1.54	11.30 ± 1.87	0.299
b*	7.10 ± 1.16	6.74 ± 1.02	7.63 ± 0.96	0.115
h	30,47 ± 1.61^{a}	30,09 ± 1.27^{a}	34,21 ± 0.97^{b}	<0.001
C*	14,00 ± 1.98	13,51 ± 1.62	13,64 ± 2.06	0.587

Meat lightness is a critical quality characteristic, as consumers prefer lighter meat and associate it with younger animals (Bañón et al., 2006). In the present trial, meat from Alpine kids was darker (lower L* values) compared to Balkan

kids, while Serbian white kids were intermediate (p=0.02) for *longissimus lumborum* (Table 1). For tenderloin (psoas major), L* values were highest for Balkan kids (38.60), with no significant differences between the two other breeds (Table 2). For the *semimembranosus* muscle, L* values were the lowest for Alpine kids (34.29) and highest for Balkan kids (36.55), while Serbian white was intermediate (Table 3). Lightness values of muscles reported in this study were lower than those reported by Santos et al. (2007), ranging from 44 to 50 in Bravia, Serrana and Bravia × Serrana breeds slaughtered at 8–11 kg. Similar values were reported by Bañón et al. (2006) for Murciano-Granadina kids meat, which had an average L* of 48.70 and Peña et al. (2009) for Criollo Cordobés and Anglonubian kids, where L* value ranged from 42.54 to 48.82. Older animals slaughtered at a higher final weight were probably the reason for the lower L* values found in this study (Peña et al., 2009). Dhanda et al. (1999) reported darker meat (L*<42) of Chevon goats. Regarding this, Marichal et al. (2003) and Argüello et al. (2005) reported a decrease of 2–4 points of L* value with an increase in slaughter weight from 6 kg to 10 kg. On the contrary, the effect of breed (Turkish Saanen, Gokceada and Malteseon goat slaughtered at 90 days of age) on lightness (L*) values of *longissimus dorsi* muscles was not significant in the research of Ekiz et al. (2010). Variations of L* values between genotypes can be explained by the differences in the meat fibre composition that influence different light scattering properties (Hughes et al., 2020). Overall, the lightness values were in the acceptable range of (L*) > 34 (Holloway and Wu, 2019).

A significant effect of genotype on a* values of goat meat was previously reported (Dhanda et al., 1999, 2003; Santos et al., 2007). The redness (a*) colour values of meat cuts were within the acceptable range from 9.5 to 19 (Holloway and Wu, 2019). In general, redness increases with the slaughter weight due to increasing the haem pigment of older animals (Lawrie, 1998). Altough, some authors found no significant differences in meat a* value with increasing the slaughter weight (Todaro et al., 2002; Peña et al., 2009). Additionally, the differences in redness values can be explained by the different muscle fibre compositions between breeds, which can influence myoglobin oxidation rate (Bakhsh et al., 2019). In the current study, the redness values of all three analyzed muscles are higher than those reported by Todaro et al. (2002) for kids slaughtered from 5 to 10 kg. However, other authors reported similar values (Dhanda et al., 2003; Santos et al., 2007). In the research of Gawat et al. (2022), meat from Boer crosses and feral goats differ in a* values for both *longissimus lumborum* and *semimembranosus* muscles, which also affected the value of

chroma (colour intensity) between genotypes and muscles. Dhanda et al. (2003) reported higher a* values for Australian feral goats than Boer crosses. Higher *longissimus lumborum* pH values of Balkan goats found in this research can be correlated to lower redness (McKeith et al., 2016; Zhang et al., 2018).

Goat slaughter weight did not affect meat yellowness (b*) value in the research of Peña et al. (2009), although b* decreases with a significant increase in animal slaughter weight in the research of Dhanda et al. (1999). In the present research, b* values significantly differ ($p=0.030$) between breeds only for *longissimus lumborum* muscle, where the highest values were found for the Serbian white breed (7.26) and lowest for the Alpine breed (6.19), while the Balkan breed was intermediate (Table 1).

Hue angle (h), as a colour saturation parameter, gives a more realistic overview of meat colour compared to single indicators, such as a* and b* and it is often used to describe meat discolouration (Emami et al., 2015). Therefore, the higher h value results from a decrease in a* relative to b* value (Luciano et al., 2009). In the present research, the higher h values of meat from indigenous breeds (Balkan and Serbian white) compared to the Alpine breed shows that a lighter colour characterizes this meat. These results agree with the findings of Dhanda et al. (2003), Marichal et al. (2003) and Argüello et al. (2005) but were much lower than those reported by Todaro et al. (2002) and Ripoll et al. (2011). Interestingly, Ekiz et al. (2010) found no significant differences in hue values of *longissimus dorsi* muscles between three goat breeds (Turkish Saanen, Gokceada and Malteseon).

Chroma value (C*) is correlated to the pigment content, and high values indicate a more vivid colour and denote a lack of greyness (Miltenburg et al., 1992). Todaro et al. (2002), Argüello et al. (2005) and Peña et al. (2009) found no differences in meat chroma values between goats slaughtered at different weights. Ripoll et al. (2011) found that chroma values were strongly correlated to yellowness ($r=0.95$; $p<0.001$). However, in the current research, there were no significant differences in C* values between breeds for all muscles analyzed. These results are not in agreement with the research of Ekiz et al. (2010), where authors found a significant difference in *longissimus dorsi* C* values between goat breeds, although the values were similar to those reported in this trial (Table 1).

Conclusion

The results obtained in this study demonstrated the significant effect of goat genotype on pH and meat colour characteristics for all three analyzed muscles,

whereas the biggest effect was established for l*ongissimus lumborum* muscle. Balkan kids had a significantly higher pH value compared to Alpino and Serbian white, which probably influenced Balkan kids' significantly higher meat lightness than Alpino. Yellowness only differed for *longissimus lumborum* muscle, whereas Serbian white kids had a higher b* value than Alpino kids. As a colour saturation characteristic, the hue angle was higher in meat from indigenous breeds (Balkan and Serbian white) than in the Alpino breed. Interestingly, all three breeds had similar redness (a*) and Chroma values (C*).

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